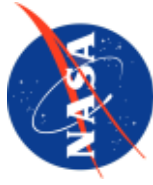


Radiometric Calibration of the AWiFS Using Vicarious Calibration Techniques

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John C. Stennis Space Center, MS 39529**

**JACIE Civil Commercial Imagery Evaluation Workshop
Fairfax, VA, USA
March 21, 2007**



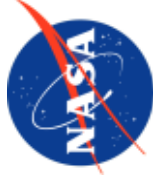
AWiFS – Advanced Wide Field Sensor

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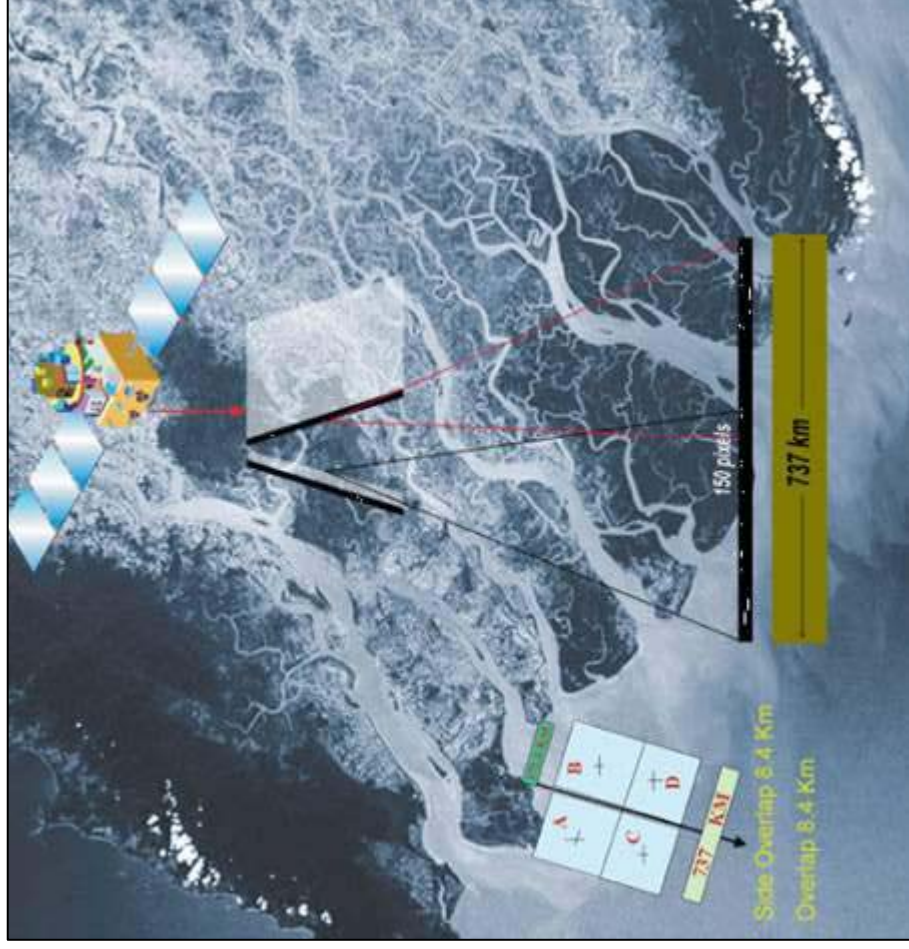
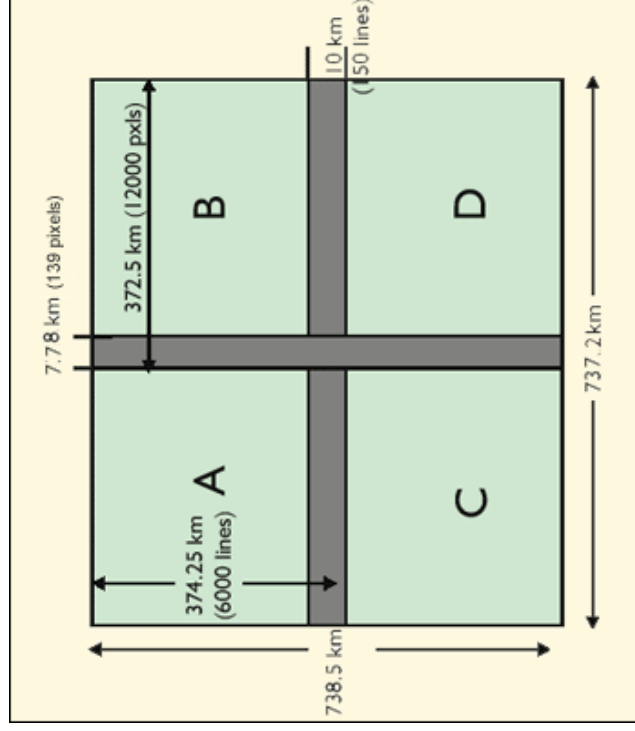
- Onboard IRS-P6 RESOURCESAT-1 satellite
 - Launched October 2003
 - Design life of 5 years
- Pushbroom architecture
- Four bands in the VNIR-SWIR spectral region
 - Green (0.52–0.59 μm), Red (0.62–0.68 μm), NIR (0.77–0.86 μm), SWIR (1.55–1.70 μm)
- Spatial resolution: 56 m (near nadir), 70 m (near edge)
- Radiometric resolution: 10 bit
- Swath: 740 km
- Repeat time: 5 days



AWiFS Collection Mode

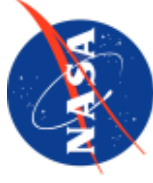


The AWiFS camera is split into two separate electro-optic modules (AWiFS-A and AWiFS-B) tilted by 11.94 degrees with respect to nadir



Source: <http://www.spaceimaging.com/products/irs/RESOURCESAT/products.htm>

Landsat 7 – AWiFS Comparison



Number of Samples

- Landsat 7: ~144 points per 40-acre field
- AWiFS: ~36 points per 40-acre field

Repeat Coverage

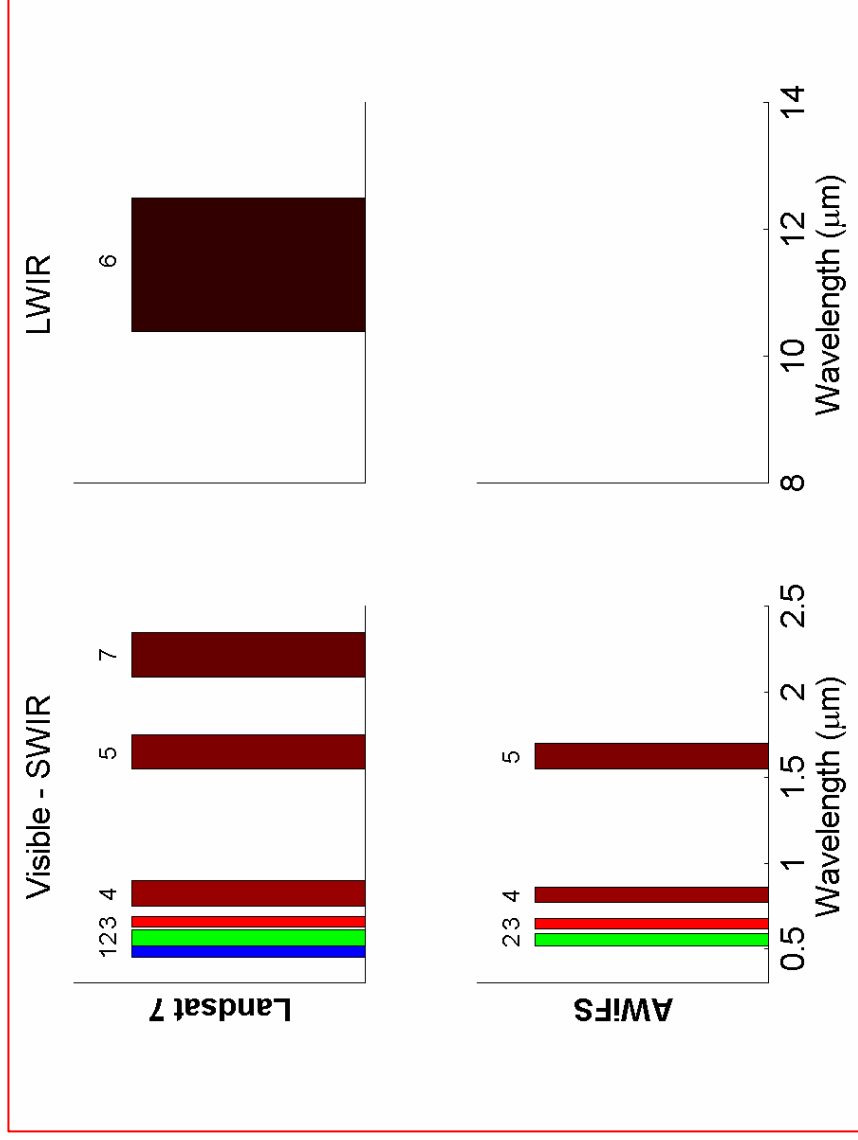
- Landsat 7: 16 days
- AWiFS: 5 days

Swath

- Landsat 7: 185 km
- AWiFS: 737 km

Bands

- Landsat 7: 7 bands
- AWiFS: 4 bands (no blue, 2.2 μm , thermal)



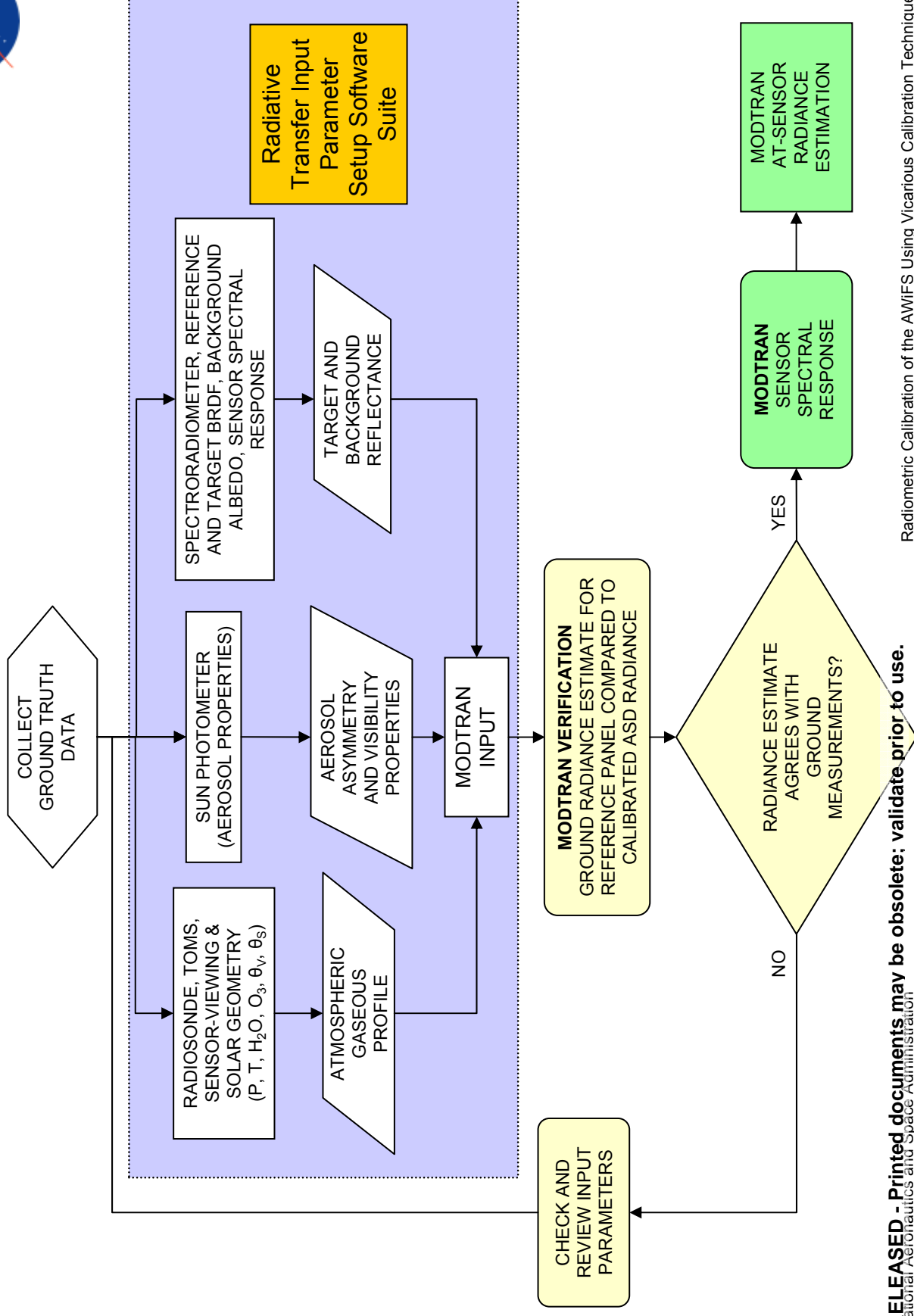
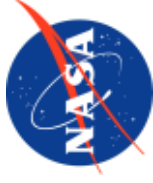
Characterization Overview



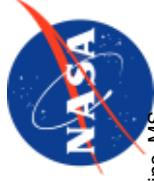
- Objective
 - Perform radiometric vicarious calibrations of imagery and compare with vendor-provided calibration coefficients
- Vicarious reflectance-based approach used
 - Ground truth collection
 - Characterize target reflectance at time of satellite overpass
 - Characterize atmosphere at time of satellite overpass
 - Use MODTRAN radiative transport code to predict at-sensor radiance
 - Compare predicted at-sensor radiance to actual radiance acquired by sensor

At-Sensor Radiance Prediction Method

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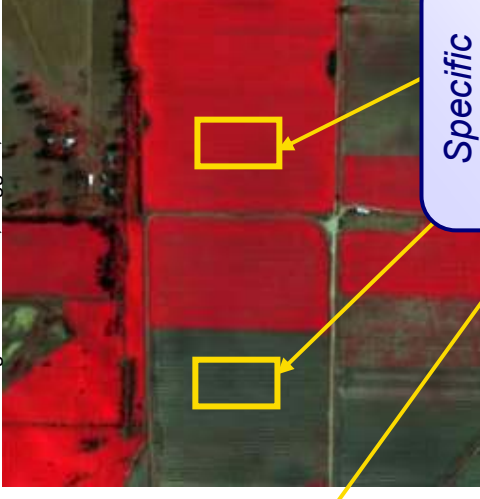
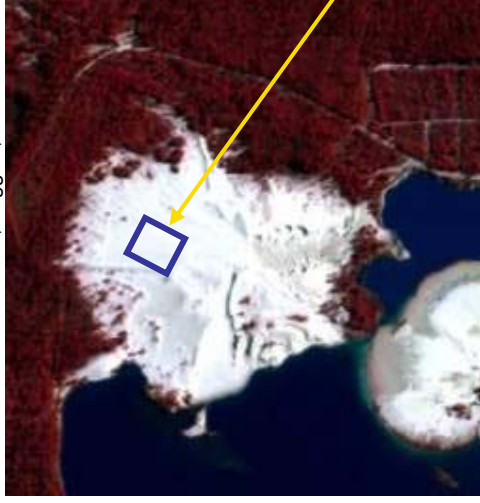


Selected Targets

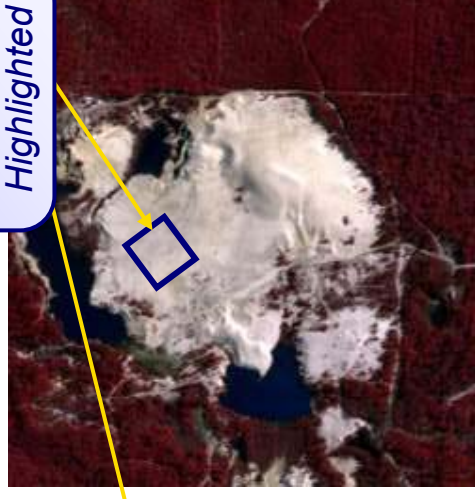


Big Level Fields, Wiggins, MS

Perkinston Gravel, Wiggins, MS



Specific
Target
Areas
Highlighted



Clear Cut field, SSC, MS

Diamond Gravel, Wiggins, MS

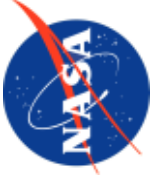
- Five selected targets of opportunity in and around Stennis Space Center are hundreds of meters across:
- Two gravel pit sand sites
 - Two large monoculture fields
 - Large tall grass field



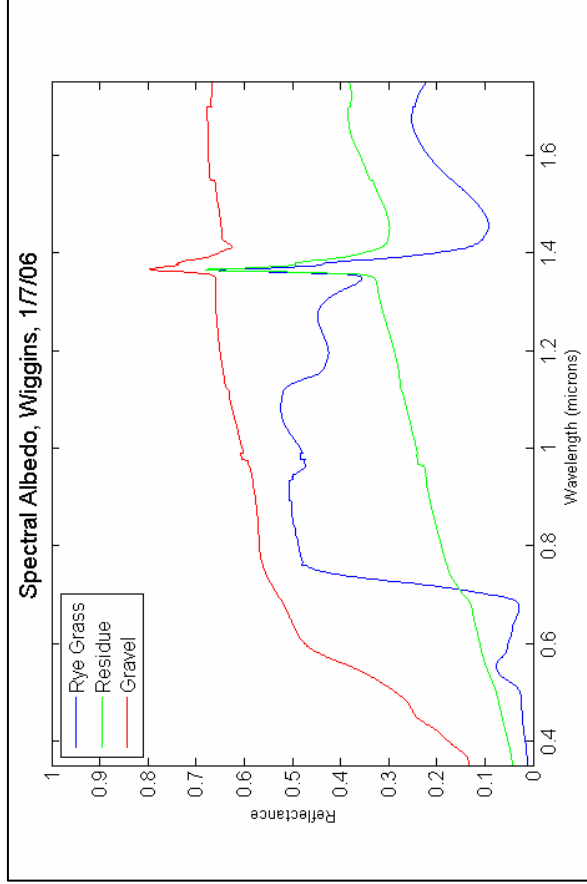
AWiFS imagery (4,3,2)
January 7, 2006

Ground Reflectance Measurements

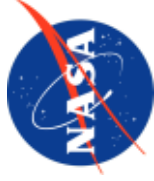
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- ASD FieldSpec® FR spectroradiometer measurements of Spectralon® panels and several target areas were taken
 - ~100 m x 200 m area of a rye grass field
 - ~100 m x 100 m area of two sand sites
 - ~100 m x 200 m area of a tall grass field
- Measurements were taken along transects aligned with the sensor azimuth
 - Measurements were taken at satellite elevation angles to account for BRDF effects
 - All measurements were taken while walking to increase spatial averaging
 - Periodic Spectralon panel measurements were taken
- All data were acquired within 30 minutes of satellite overpass



RELEASED - Printed documents may be obsolete; validate prior to use.
National Aeronautics and Space Administration



SSC Calibration and Characterization of ASD FieldSpec Spectroradiometers

- NASA SSC maintains four ASD spectroradiometers
 - Laboratory transfer radiometers
 - Ground surface reflectance and atmospheric measurements for field collection activities
- Radiometric Calibration
 - NIST-calibrated integrating sphere serves as source with known spectral radiance
- Spectral Calibration
 - Laser and pen lamp illumination of integrating sphere
- Environmental Testing
 - Temperature stability tests performed in environmental chamber



Atmospheric Measurements



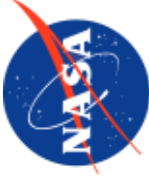
- Direct solar irradiance data for visibility estimation collected from early morning through solar noon with automated solar radiometers (optical depth/transmission)
- Total and diffuse solar irradiance for aerosol scattering estimation collected from early morning through solar noon with multi-filter rotating shadowband radiometers (diffuse-to-global ratio)
- Other atmospheric parameters, such as total column ozone and water vapor, determined using MODIS and OMI satellite data



Automated Solar Radiometer



Multifilter Rotating Shadowband Radiometer



Novel Hyperspectral Sun Photometer

Stennis Space Center

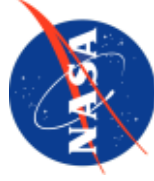
- Direct and diffuse irradiance derived from ASD radiance measurements of a characterized 99% reflectance Spectralon panel
- NIST-traceable calibration performed in laboratory
 - Instrument calibration independent of Langley regression
 - Field measurements required only at the time of overpass
- Used to measure
 - Optical depth/transmission
 - Diffuse-to-global ratio
- Technique uses equipment already in the field



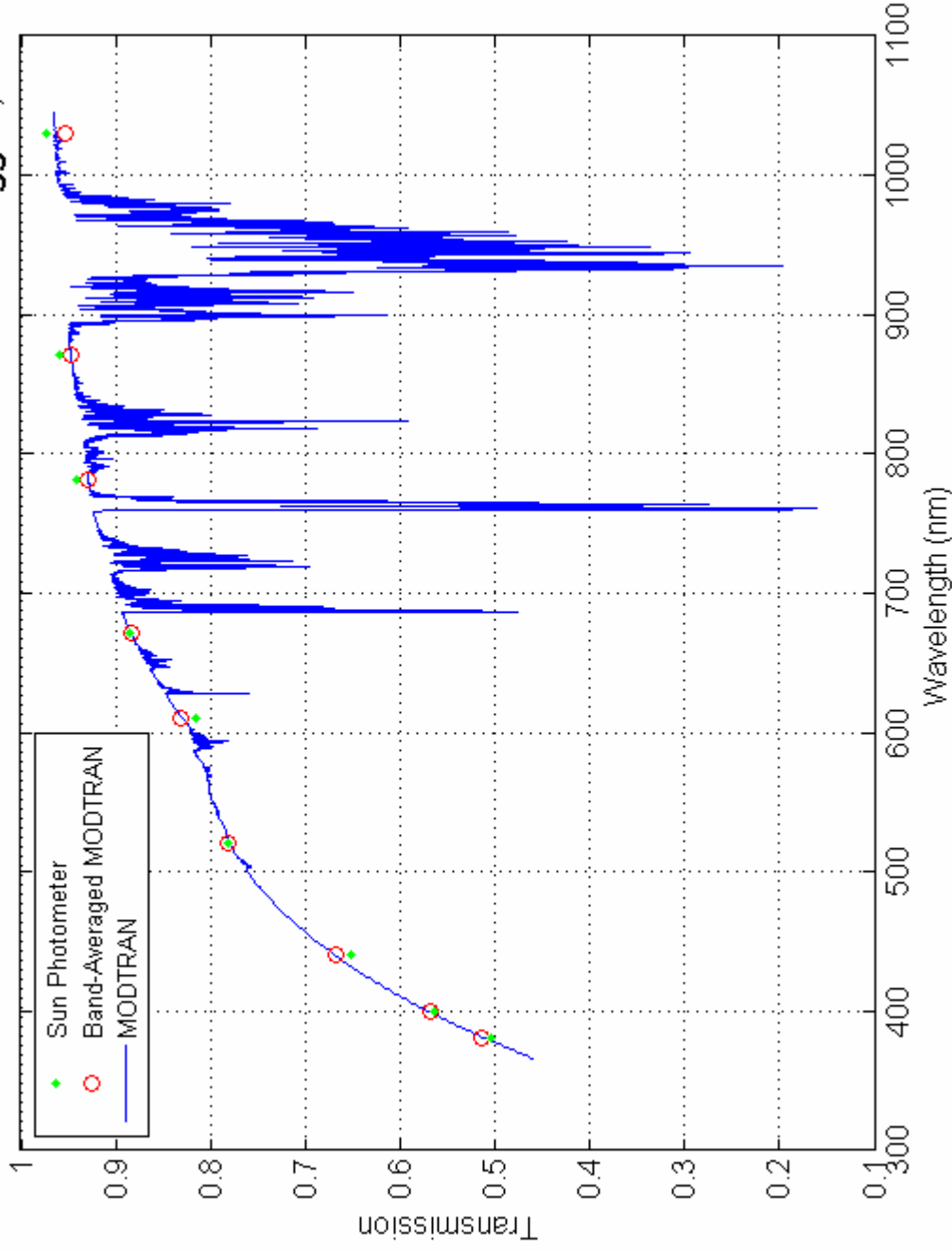
*Novel Hyperspectral
Sun Photometer Setup*

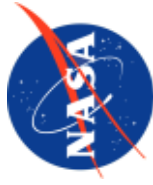
Visibility Estimation

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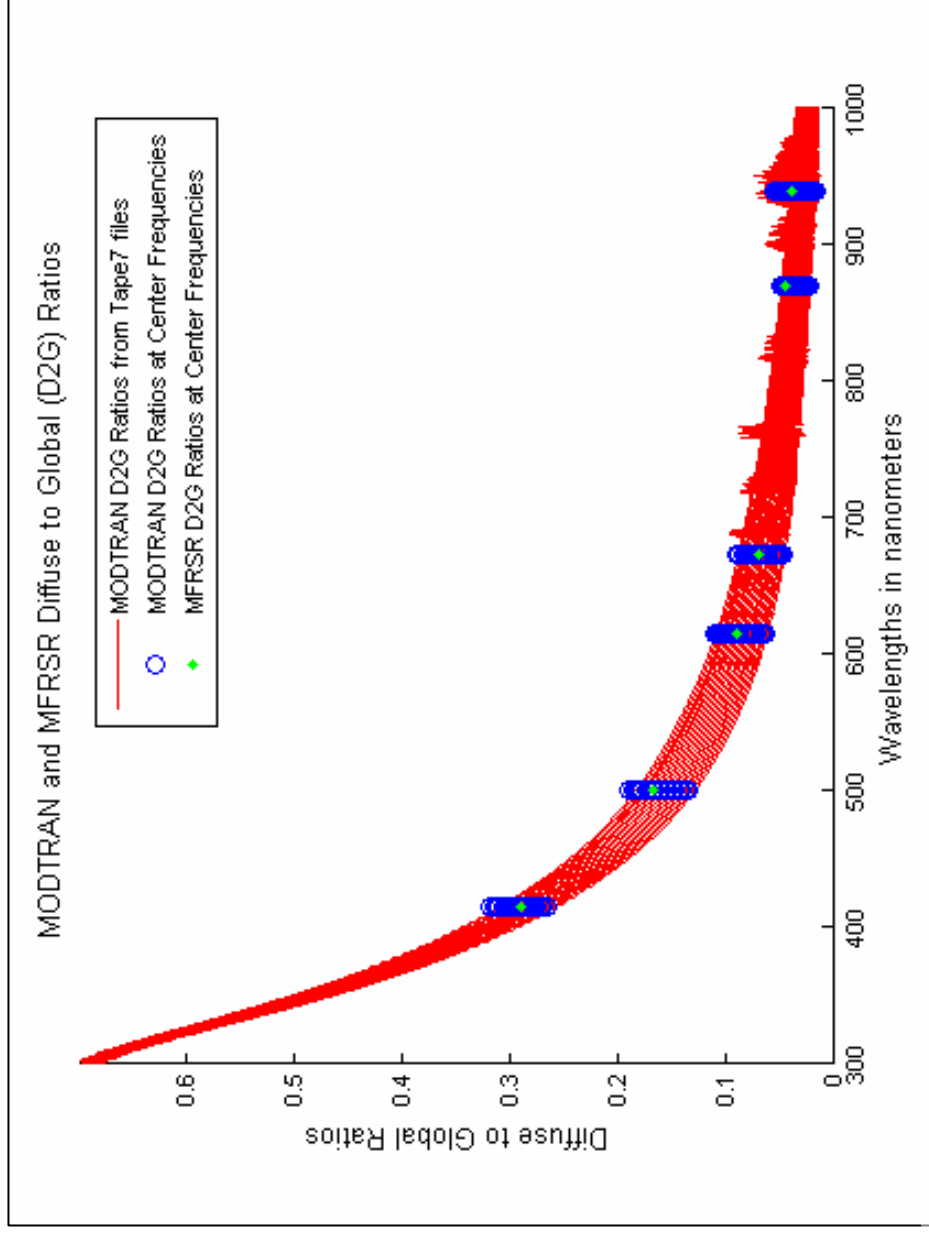
Sun Photometer and MODTRAN Predicted Transmissions for Wiggins, 3/15/06



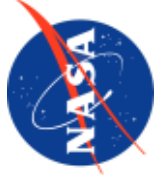


Aerosol Scattering

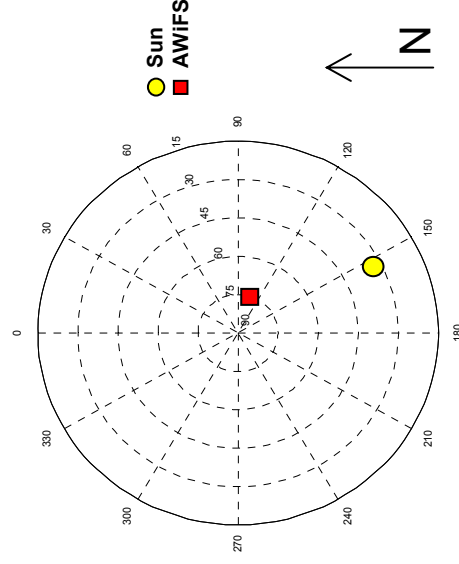
The asymmetry factor for the aerosol scattering phase function is estimated by comparing MODTRAN output diffuse-to-global ratio values to MFRSR measured diffuse-to-global ratio values



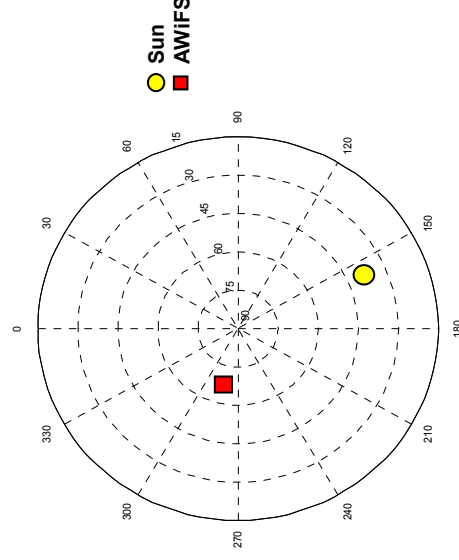
Data Acquisitions



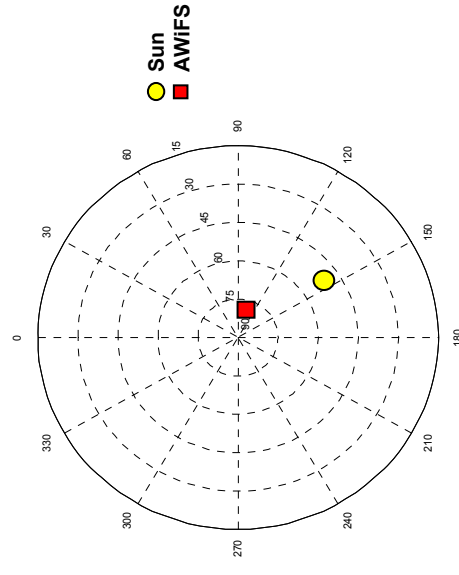
Date	Camera	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun	
					Elevation	Azimuth
Jan 7, 2006	A	16:32	74.9 deg	103 deg	32.6 deg	155.0 deg
Jan 25, 2006	B	16:57	66.5 deg	282 deg	37.4 deg	158.3 deg
Mar 15, 2006	A	16:38	81.2 deg	103 deg	51.2 deg	143.7 deg



Wiggins, MS, 1/7/06



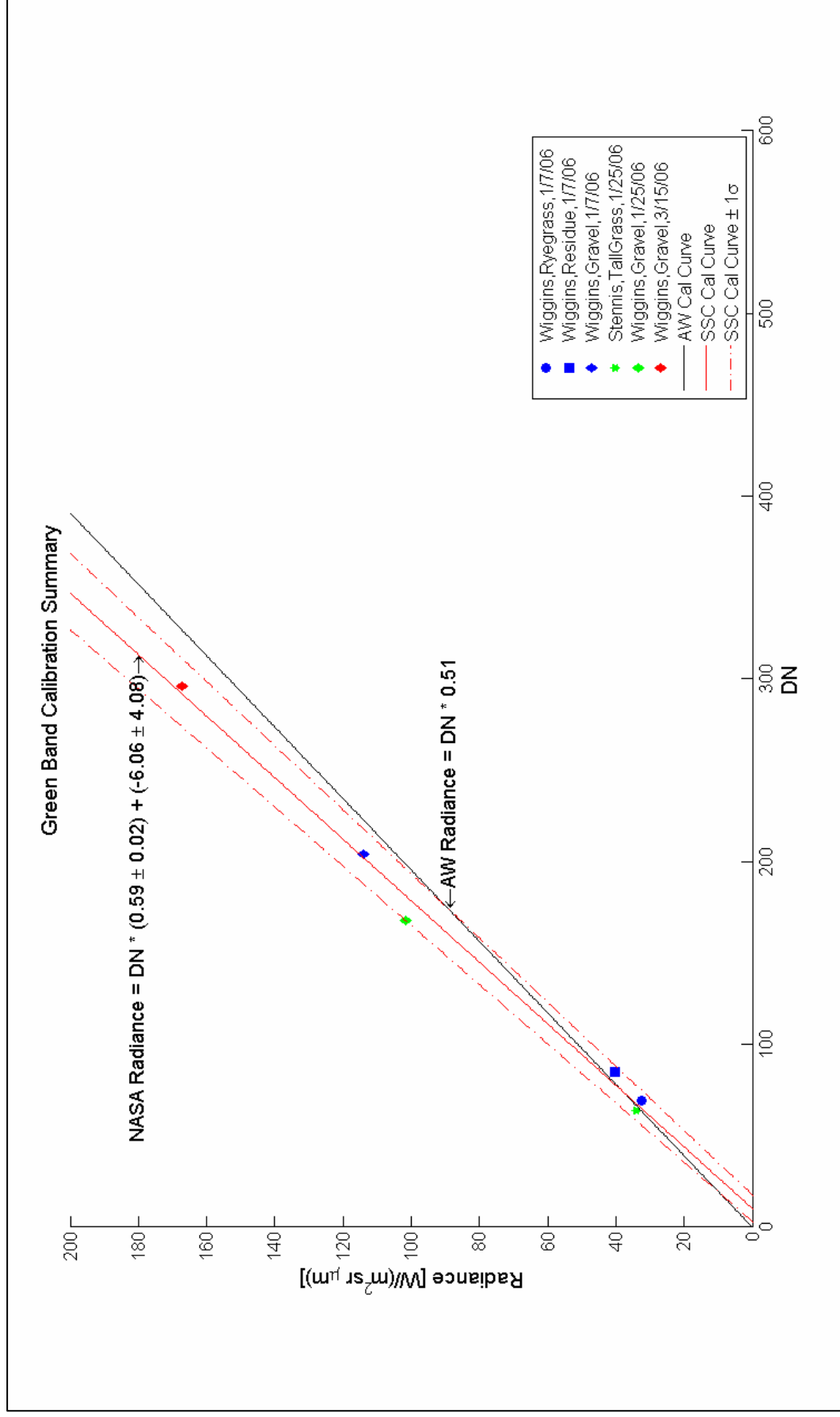
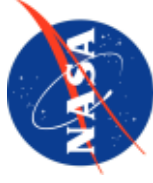
Wiggins, MS, 1/25/06

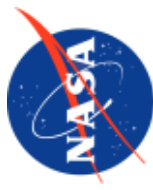


Wiggins, MS, 3/15/06

Green Band Calibration Summary

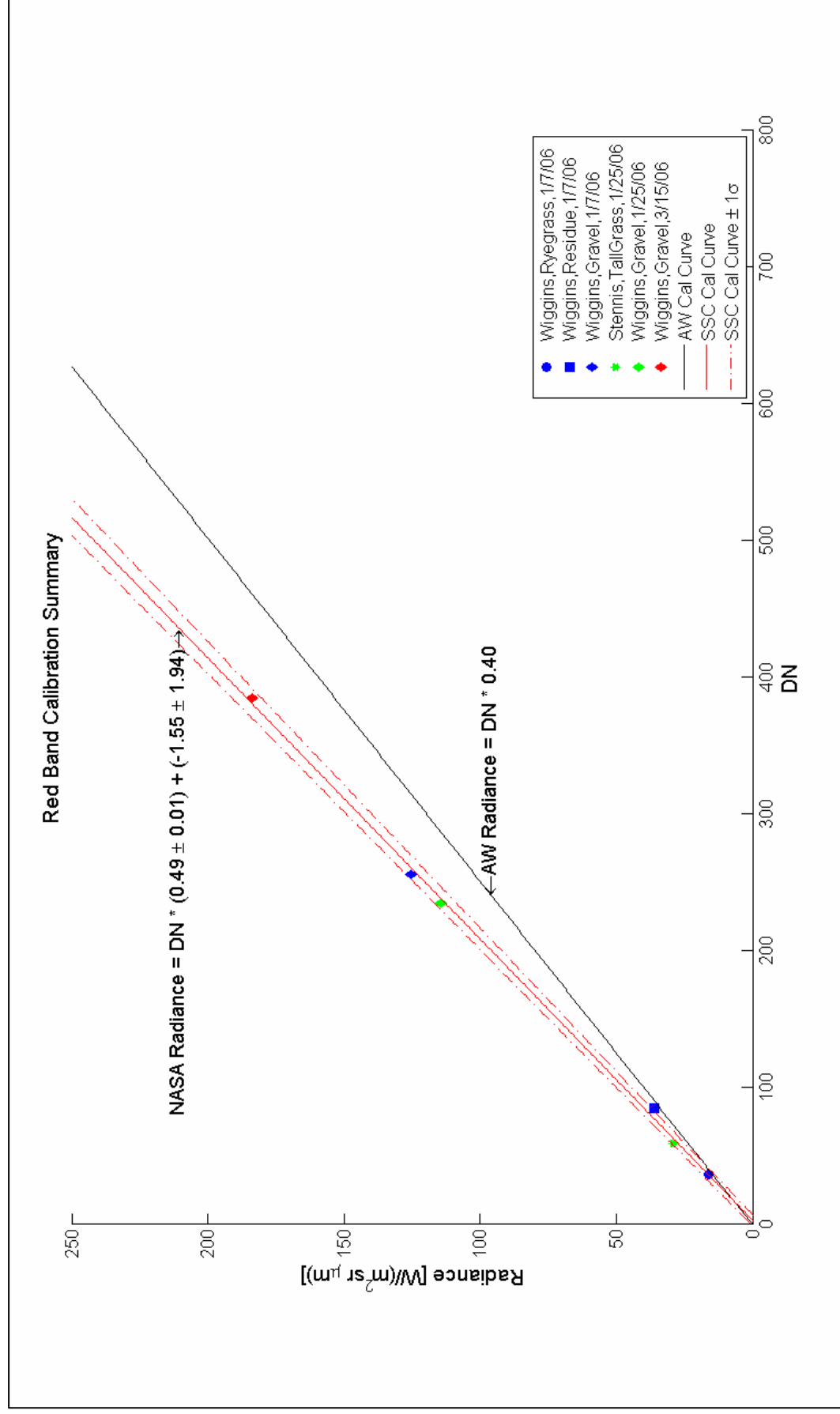
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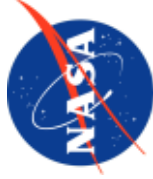
Red Band Calibration Summary

Stennis Space Center

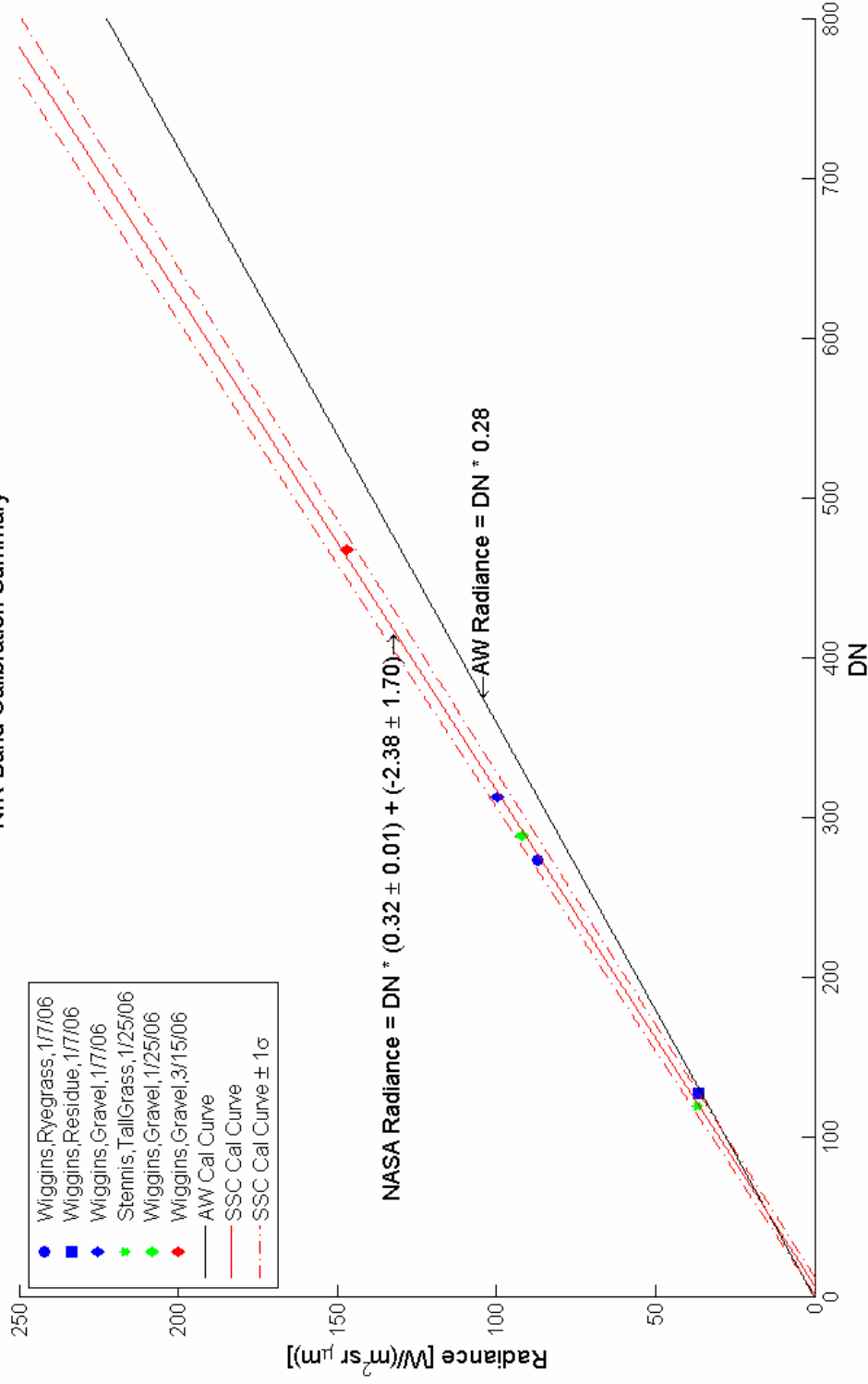


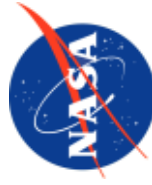
NIR Band Calibration Summary

Stennis Space Center



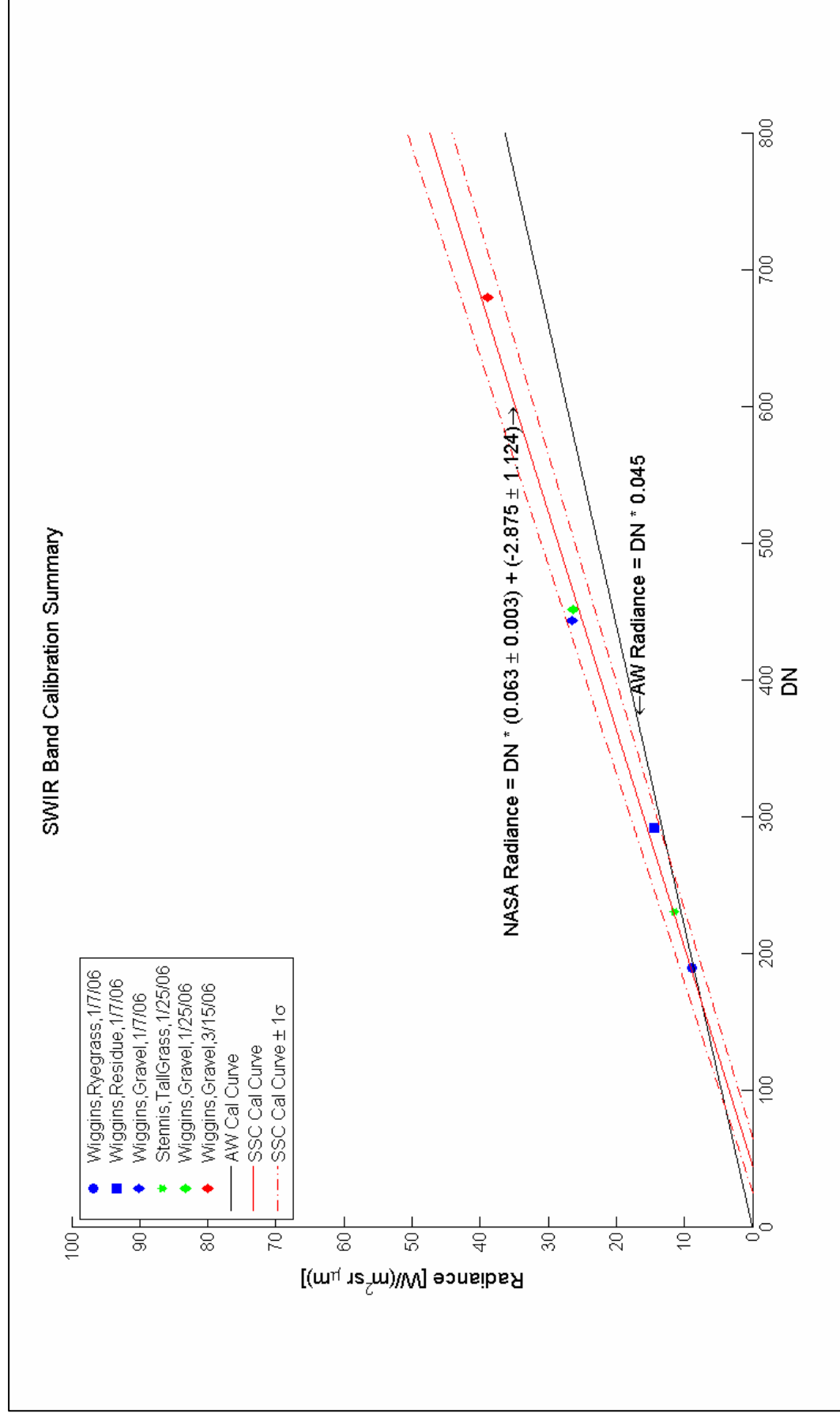
NIR Band Calibration Summary

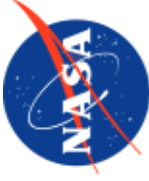




SWIR Band Calibration Summary

Stennis Space Center



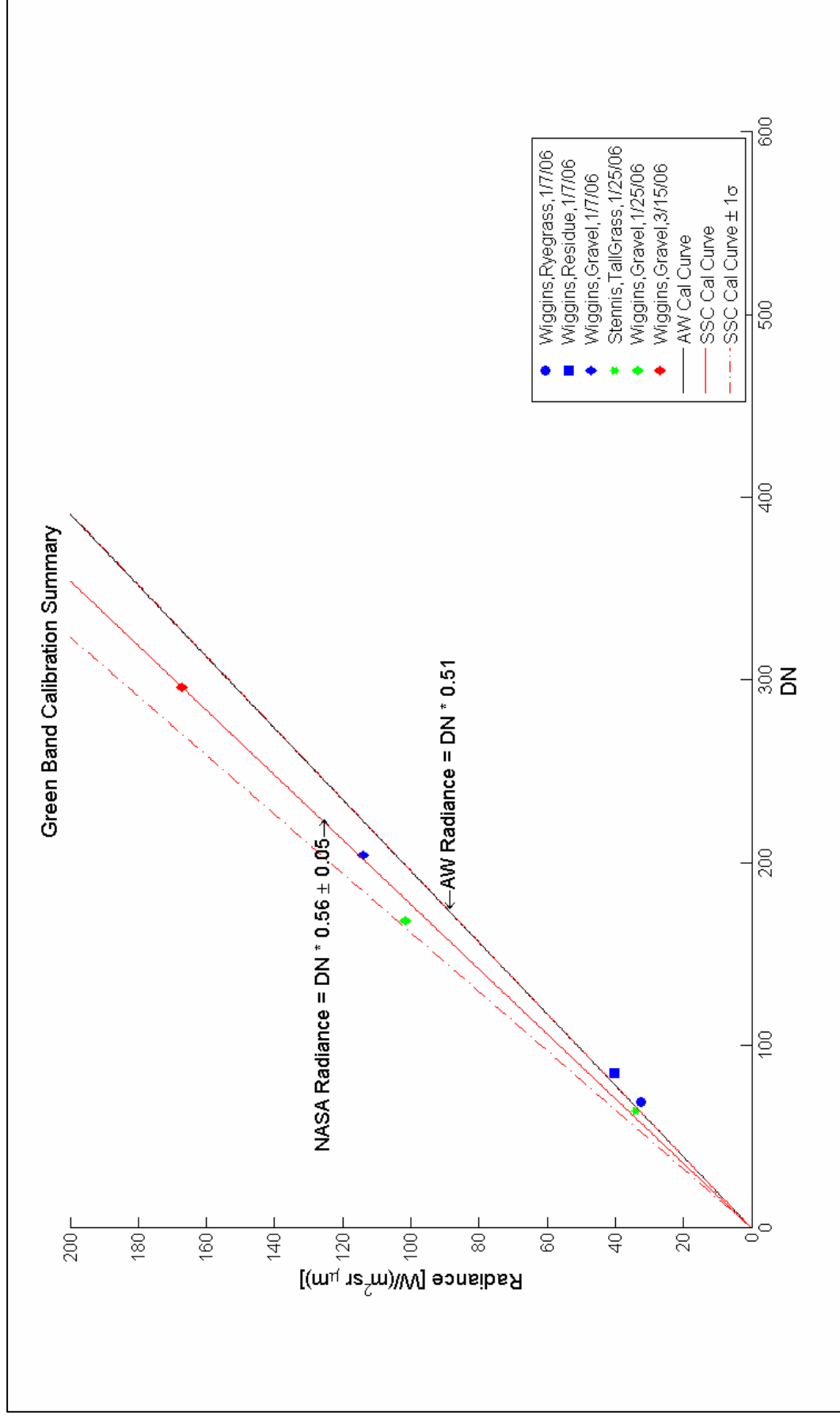
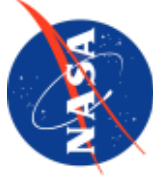


Radiometric Calibration Coefficients

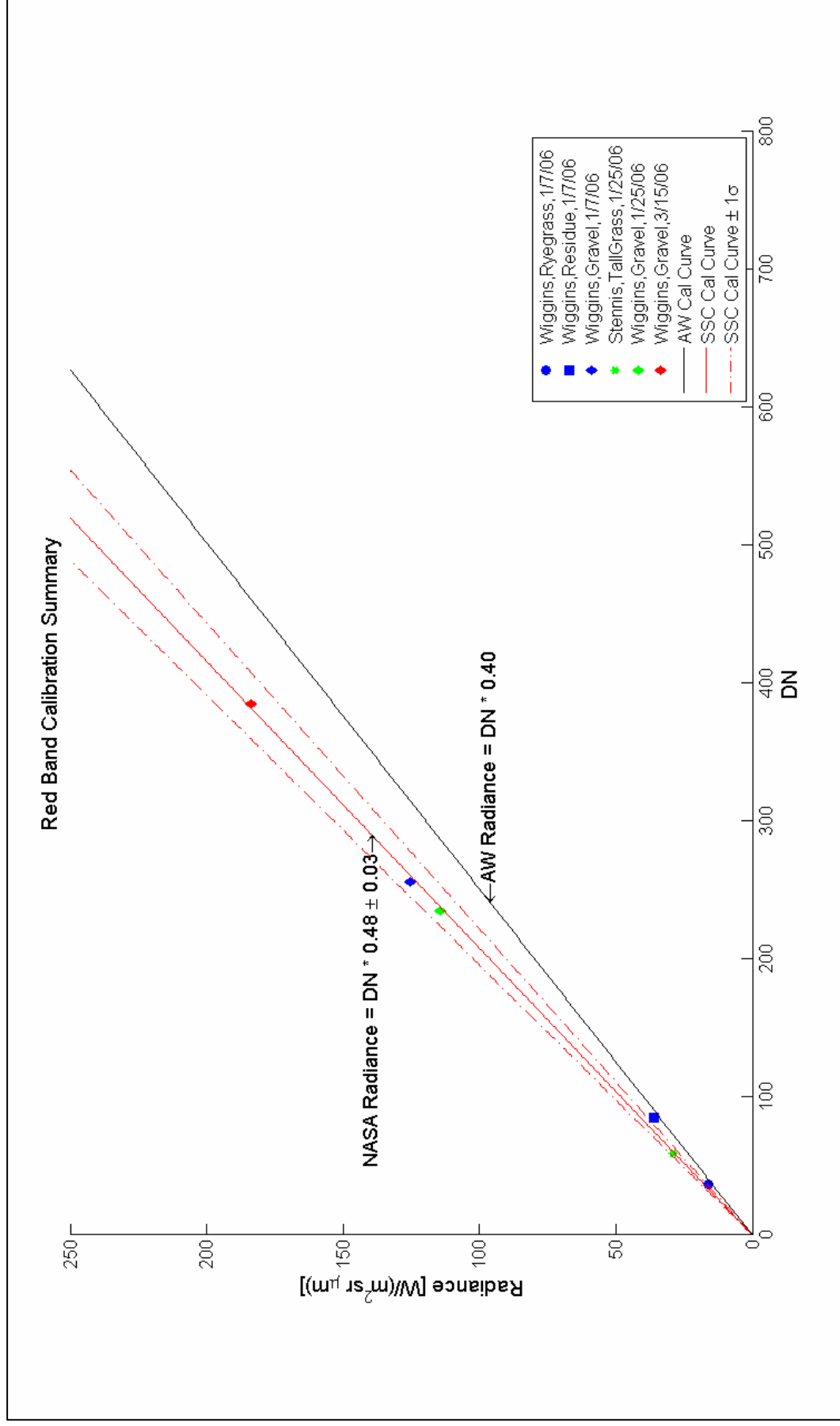
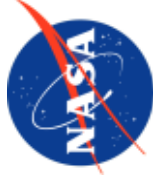
Stennis Space Center

	Green	Red	NIR	SWIR
NASA Estimate 2006				
Cal Coeff (W/m ² sr μm DN)	0.59 ± 0.02	0.49 ± 0.01	0.32 ± 0.01	0.063 ± 0.003
Offset	-6.06 ± 4.08	-1.55 ± 1.94	-2.38 ± 1.70	-2.88 ± 1.12
NASA Estimate 2005				
Cal Coeff (W/m ² sr μm DN)	0.60 ± 0.02	0.46 ± 0.01	0.31 ± 0.02	0.056 ± 0.004
Offset	-5.49 ± 5.36	2.60 ± 3.89	-3.11 ± 6.69	-2.82 ± 2.15
AWiFS Provided				
Cal Coeff (W/m ² sr μm DN)	0.51	0.40	0.28	0.045
Offset	0	0	0	0

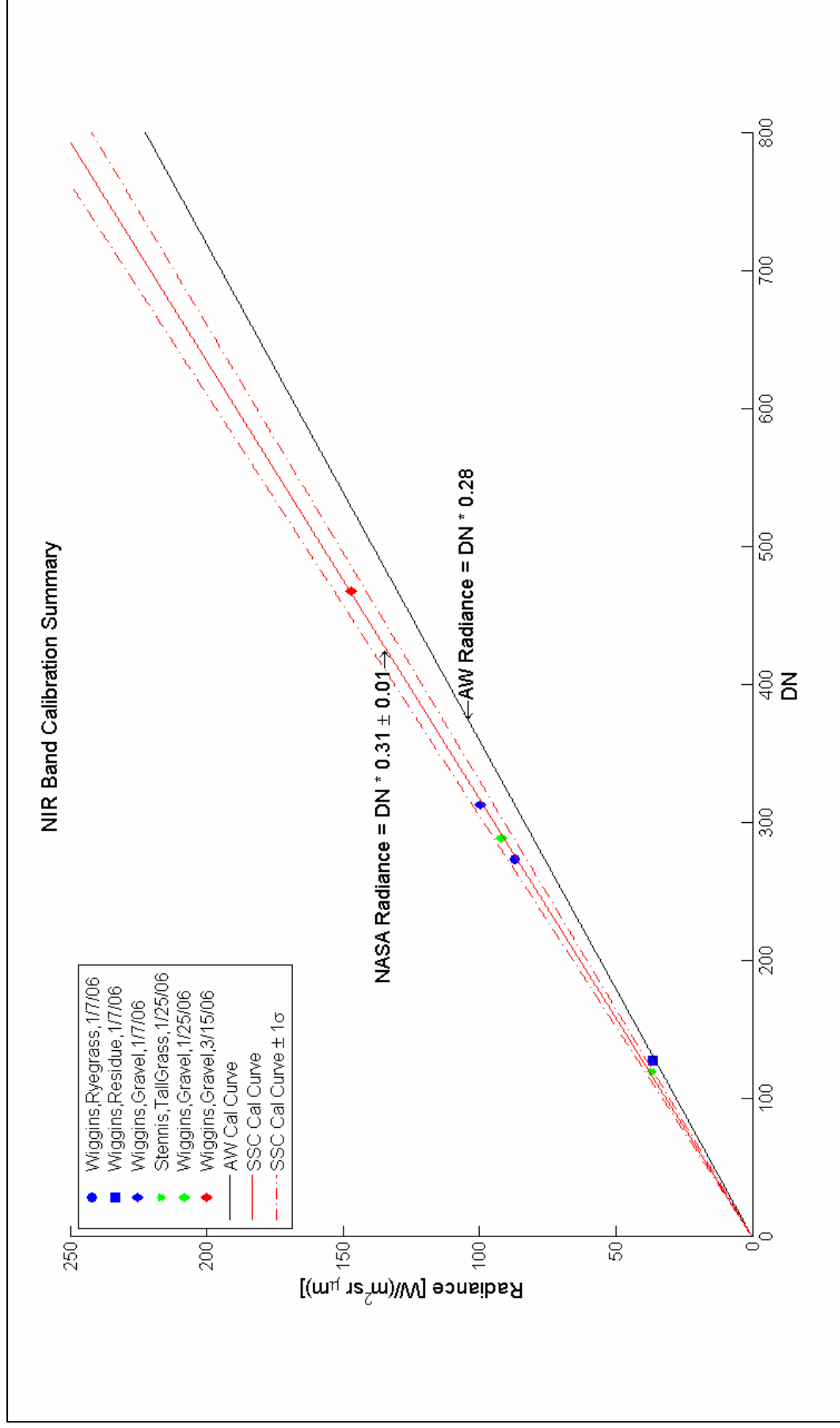
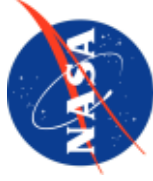
Green Band Calibration Summary (Zero-Offset)



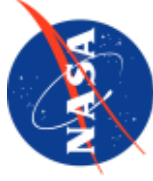
Red Band Calibration Summary (Zero-Offset)



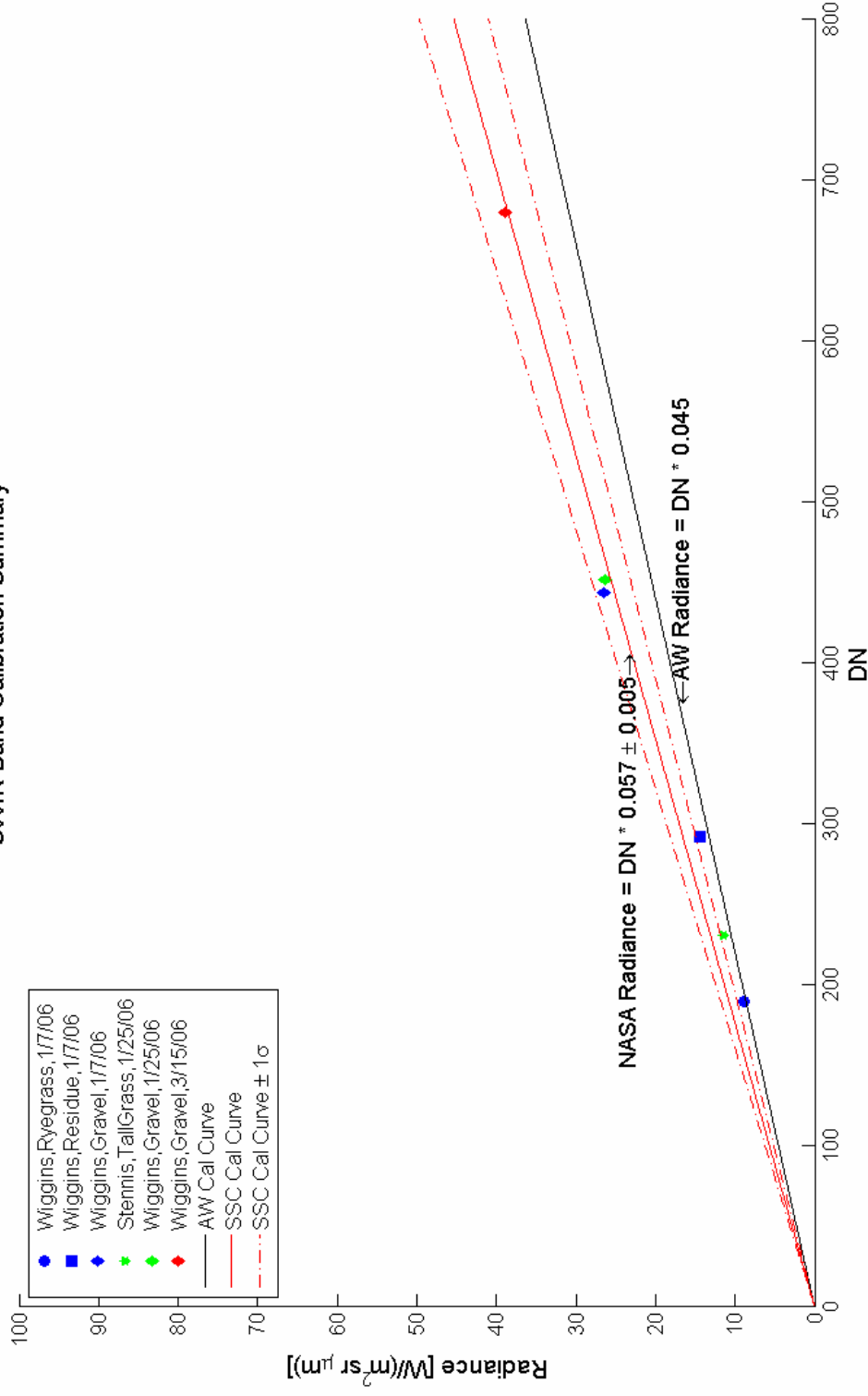
NIR Band Calibration Summary (Zero-Offset)



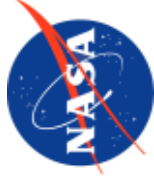
SWIR Band Calibration Summary (Zero-Offset)



SWIR Band Calibration Summary



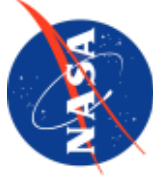
Initial Radiometric Calibration Coefficients (Zero-Offset)



Band	NASA 2006 Estimate [W/m ² sr μm DN]	NASA 2005 Estimate [W/m ² sr μm DN]	AWiFS Provided [W/m ² sr μm DN]	% Difference (AWiFS vs. NASA 2006)
Green	0.56 ± 0.05	0.58 ± 0.06	0.51	8.9%
Red	0.48 ± 0.03	0.47 ± 0.05	0.40	16.7%
NIR	0.31 ± 0.01	0.30 ± 0.02	0.28	9.7%
SWIR	0.057 ± 0.005	0.052 ± 0.005	0.045	21.1%

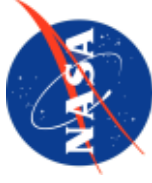
Percent difference is calculated by $(1 - \text{AWiFS/NASA Mean})$

AWiFS Results Summary



- The AWiFS calibration coefficients agree reasonably well with the NASA estimate
 - Limited characterization points in 2006
 - Red and SWIR band percent differences will be reviewed
- The AWiFS radiometric calibration coefficients appear stable over a 1-year period (March 2005–March 2006)
- The NASA team will continue to assess AWiFS radiometric accuracy

Contributors



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